OPERATING INSTRUCTIONS

"THE REED" ELECTRONIC ENGINEERS' SLIDE RULE

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OPERATING INSTRUCTIONS.

THE "REED" ELECTRONIC ENGINEER'S SLIDE RULE.

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SERVICE SLIDE RULE
SYDNEY

INTRODUCTION.

The Slide Rule in its many forms is a valuable mathematical tool employed by engineers, physicists, and scientists for the rapid solution of problems. The "REED" Electronic Engineer's Slide Rule has been designed to provide a group of scales within one instrument, meeting the requirements of the ever growing army of workers engaged in the various branches of Electronic Engineering.

Before describing the functions of the various scales, a few words as to the construction, and care of the slide rule will prove of assistance to those entering their life long association with an instrument which will prove an indispensable assistant in the solution of a surprisingly wide range of problems.

1. Treat your Slide Rule as a precision instrument, keeping it clean, and never leaving it uncovered on desk or bench for protracted periods to collect dust or suffer accidental contact with tools or equipment which may injure the surface of its scales. The carrying case for this slide rule has been specially treated to ensure long life under hard working conditions.

2. At intervals, the slides and cursor should be cleaned by rubbing with a soft cloth after breathing on the slides and glass, similar to the cleaning operation made use of in connection with spectacles. Keeping the slides free from dust will ensure smooth operation and elimination of minute surface scratching; an important point which reflects the character of an engineer in the treatment of this most important tool of trade.

3. Lubrication of the slides at regular intervals will ensure smooth operation, and for this, a light application of paraffin wax to the slide is recommended. Do not use candle wax, as the stearine content of this wax will cause corrosion and gumming; the grade of paraffin wax sold for laundry purposes makes an excellent lubricant. Oil or spirit of any kind should not be applied to the surface of the slide rule. Alcohol or methylated spirit has a solvent action on the scale material of the slide rule, and will cause distortion and shrinkage.

GENERAL DESCRIPTION.

A Slide Rule consists of three main parts; (a) The Body, (b) The Slide, and (c) The Cursor. Sections (a) and (b) are engraved with the various scales, and (c) is a sliding glass rectangle marked with cross lines for alignment with the divisions of (a) and (b).

The Electronic Engineer's Slide Rule is provided with the following scales and special markings:—

(i) Standard A — D and B — C scales respectively on Body and Slide.

(ii) Cube Scale on the upper portion of the Body, calibrated relative to the "D" scale.

(iii) Logarithm scale on the lower portion of the Body, calibrated relative to the "D" scale.

(iv) Inductance calculating factor (Nagaoka) on the centre recess of the Body, calibrated relative to the Slide and the "D" scale.

(v) Inverse scale on the centre front of the slide, relative to the "D" scale.

(vi) Sine Scale on the top rear of the Slide, calibrated relative to the "D" scale.

(vii) Tangent scale on the bottom rear of the Slide, calibrated relative to the "D" scale.

(viii) Combined Sine and Tangent scale for small angles on the centre rear of the slide calibrated relative to the "D" scale, and providing the equivalent of a trigonometrical scale twice the length normal for a Ten inch Slide Rule.

(ix) Special markings $\sim$, λ, and Kc/s on the "B" scale for the calculation respectively of: Resonant

Frequency in cycles per second of circuits with constants expressed in Henries and Microfarads. Wavelength in metres of resonant circuits with constants expressed in Microhenries and milli-Microfarads. Resonant Frequency of the former circuit expressed in Kilocycles per second.

(x) Special markings e", e', ee"), C and C 1 on Scales "C" and "D" for rapid calculations of: Values of arc for the sexagesimal and centisimal divisions of circles. Sine and Tangent functions of very small angles. Simplified determination of areas of circles and volumes of cylinders.

(xi) Edge scales in centimetres and inches.

(xii) Tables of useful constants and formulæ on the rear of the Slide Rule Body.

OPERATING INSTRUCTIONS.

The various scales on the Slide Rule are marked in logarithmic proportion, permitting multiplication and division to be performed by the addition and subtraction of these spaces. This will be obvious to those familiar with the use of logarithms, for in dealing with logarithms, multiplication is replaced by addition, and division by subtraction. The graduations of the Slide Rule are not proportional to the numbers on these graduations, but proportional to the logarithms of the numbers.

Scales "A" and "B" are graduated in square relationship to scales "C" and 'D" permitting immediate solution of problems of squares and square roots by one setting of the Cursor. Similarly, the Cube scale, calibrated

relative to the "D" scale gives cube or cube root solutions when both scales are aligned with the Cursor.

For simple calculations in multiplication and division the "C" and "D" scale should be employed, and a mental approximation of the position of the decimal point relative to the significant figures will suffice. However, when the factors in the calculation are more than two, and involve numbers varying considerably in magnitude, the rule for the determination of the decimal point in a product is:—

"The number of digits in a product (multiplication) is the *same* as the sum of the digits of the two factors, if the multiplication is performed with the Slide projecting to the *left*; while it is one *less* if the slide projects to the *right*. The same rule applies if there are more than two factors; the sum of the digits of all the factors is obtained and "1" subtracted each time a multiplication is performed with the Slide to the right. If a number is greater than '1" the number of digits means the number of figures to the *left* of the decimal point, while if the number is *less* than "1," and starts with cyphers, the number of digits means the number of cyphers coming *immediately after* the decimal point.

EXAMPLE. Find the product of 2.3 x 3.9 x 0.0058.

Place the left hand index "1" of scale "C" over 2.3 on scale "D," and move the Cursor to 3.9 on Scale "C," with the slide projecting to the right. Now multiply by 0.0058 by placing the right hand index "10" of scale "C" under the Cursor line and read off the final product on Scale "D" under 5.9 on Scale "C" with the Slide projecting to the left. The final product gives a nominal figure of 5.2, and applying the abovementioned rule the position

of the decimal point is determined as follows:—The number of digits in the original factors is $1 + 1 - 2 = 0$; from which must be subtracted 1 since *one* multiplication was performed with the Slide projecting to the *right.* This indicates that the number of digits in the product must be — 1, and consequently the product is 0.052."

The rule for determining the position of the decimal point in a quotient (division) is:—

The number of digits in a quotient is the *same* as the *excess* of the number of digits in the dividend over the number in the divisor, if the slide projects to the LEFT; while it is *one more* if the slide projects to the right.

EXAMPLE. Divide 5.2 by 0.013.

Place 1.3 on Scale 'C" over 5.2 on Scale "D," with the Slide projecting to the right. The quotient gives a nominal figure of 4 under the left-hand index "1" of scale "C." Determining the position of the decimal point by the abovementioned rule, the number of digits is found to be $1 - (-1) + 1 = 3$. (The figures are added algebraically) consequently the quotient is 400.

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LOGARITHMIC VALUES.

These are determined by direct alignment with the "D" scale permitting greater accuracy and speedier calculations than that possible with Slides Rules having the Logarithm scale on the *rear* of the Slide. The Logarithm of a number to a base of 10, is the index of the power to which the base must be raised to equal that number, and consists of two parts called the *Characteristic* and the *Mantissa,* the rule being:—

"The characteristic of the logarithm of a number *greater* than "1" is *positive* and is *one less* than the number of digits *before* the decimal point. The characteristic for a number *less* than "1" is *negative* and is *one more* than the number of cyphers *immediately after* the decimal point. The Mantissæ of logarithms of *all numbers* having the *same* significant figures are the *same* and come to the right of the decimal point. It is the Mantissa of the logarithm which is read from the Logarithm Scale of the Slide Rule.

EXAMPLES.

$\log.\ 3.16 = 0.5$

$\log.\ 0.0316 = \log\ (3.16 \text{ x } 10^{-2}) = 0.5 - 2 = \bar{2}.5$

$\log.\ 31.6 = \log\ (3.16 \text{ x } 10^{1}) = 0.5 + 1 = 1.5$

$\log.\ 3160 = \log.\ (3.16 \text{ x } 10^{3}) = 0.5 + 3 = 3.5$

Powers and roots higher than squares, cubes, fourth and sixth may be calculated by a simple application of Logarithms. (Squares and cubes are self evident. Fourth roots and powers are obtained by extracting the square root twice, or taking two squares respectively, while sixth roots and powers require the extraction of a square root, plus a cube root or the raising to a square, followed by a cube power.)

EXAMPLE. (a) Find the 5.2 power of 3.6.

$= \text{antilog of } 5.2 \log 3.6 = \text{antilog of } 5.2 \times 0.5563.$

$= \text{antilog of } 2.92 = 100 \times \text{antilog of } 0.92 = 832.$

(b) Find the 5th root of 0.2.

$= \text{antilog of } 1/5\text{th of log. } 0.2.$

$= \text{antilog of } 1/5\text{th of } \bar{1}.301.$

$= \text{antilog of } 1/5\ (\bar{5} + 4.301) = \text{antilog of } \bar{1}.862$
$= 0.728.$

NOTE. If it is necessary to divide a logarithm with a negative characteristic by a number, the negative characteristic is *increased* until it is a *multiple* of the *divisor*, *compensation* being made by *adding* the necessary *positive* integer to the characteristic as in the above example.

(c) Find the 5.34 root of 0.000000746.

$= \text{antilog of log } 0.000000746 \text{ divided by } 5.34.$

$= \text{antilog of } \bar{7}.8725 \text{ divided by } 5.34.$

$= \text{antilog of } \bar{7} + 0.8725\ (-6.1275) \text{ divided by } 5.34.$

$= \text{antilog of } -6.1275 \text{ divided by } 5.34 = \text{antilog of } -1.147.$

Converting to a figure with a negative characteristic and a positive Mantissa, $-1.147 = \bar{2} + 0.853 = \bar{2}.853$

antilog $\bar{2}.853 = 0.0713.$

(For additional information, the student is referred to any standard work on Trigonometry and Logarithms.)

TRIGONOMETRICAL SCALES.

The Sine and Tangent scales on the reverse of the Slide are calibrated relative to the "C" and "D" scales. Sines for angles between the limits of 5 deg. 44 mins. and 90 degrees may be read by placing the desired angle on the "S" scale at the upper mark in the notch on the right of the rear of the Body, and reading the Sine of the angle on the "C" scale *above* the right hand index "10" of the "D" scale. The sine of 90 degrees being 1.0, and that of 5 deg. 44mins. being 0.1.

Tangents between the limits of 45 degrees and 5 deg. 44 mins. may be read by placing the desired angle on the "T" scale at the mark in the notch at the left of the rear of the Body, and reading the Tangent of the angle on the "C" scale *above* the left hand index "1" of the "D" scale. Tangent values for angles smaller than 5 deg. 44 mins. may be obtained with sufficient accuracy from the combined "S & T" scale on the centre rear of the slide; these values, which lie between 0.1 and 0.01 (for angles between 5 deg. 44 mins. and 34 mins.) are read by placing the lower mark in the notch at the right of the rear of the Body, and reading the Sine or Tangent *above* the right hand index "10" of the "D" scale.

Should the problem being solved require frequent reference to Sine or Tangent values, these functions may be obtained more readily by direct alignment on the centre line of the Cursor by reversing the Slide, placing the Sine and Tangent scales on the face. All values are now read relative to the "D" scale; the magnitude being similar as outlined above.

Tangents for angles above 45 degrees and below 84 deg. 16 mins. may be read by taking the reciprocal or

co-tangent of the desired angle, setting at the mark in the left notch of the rear Body and reading the Tangent on the reciprocal scale (in the centre of the front of the slide) with the Cursor line set at the left hand index "1" of the "D" scale. Tangents between 84 deg. 16 mins. and 89 deg. 26 mins are read from the reciprocal scale by setting the cotangent (or reciprocal) of the desired angle on the S and T scale at the lower mark in the right notch of the rear Body, with the aligning Cursor line set at the right hand index "10" of the "D" scale. Multiply the significant figures on the reciprocal scale by 10.

For very small angles—less than 34 minutes—the Sine and tangent values cannot be read directly from the above scales.

Calculate the number of seconds in the small angle for which the tangent or sine is desired, then divide by 206265 (the number of seconds in a radian). Scales "C" and "D" are marked with a special engraving e" which facilitates this calculation. Set the mark e" on Scale "C" over the significant figures on scale "D" corresponding to the number of seconds in the angle, and read the significant figures of the Sine or Tangent on Scale "D," below the right hand index "10" or left hand index "1" of Scale "C." Now apply the previously mentioned rule for the determination of the decimal point.

EXAMPLE. Find the sine or tangent of 20 minutes = 1200 seconds.

$= \frac{1200}{206265}$ = significant figure of 5.83, with slide projecting to the left. The difference in digits of dividend and divisor in this example is —2 giving result as 0.00583.

(Refer to previously stated rule for division.)

A similar calculation with the angle expressed in minutes may be performed by using the symbol e' on the "C" scale over the significant figure on the "D" scale.

The decimal value of the arc (radian) of a circle may be calculated from the angle by taking the minutes or seconds of the angle and dividing respectively by the symbol e' or e".

Calculations in the French or Centesimal method of angle division may be carried out by employing the symbol e,, on the "C" scale. While the Centesimal division may be of use in special instances associated with metrically divided instrument scales it is never employed in practice for trigonometrical calculations.

Centesimal Subdivision.

1 Right angle	=	100 Grades.
1 Grade	=	100 Minutes.
1 Minute	=	100 Seconds.

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CIRCLE CALCULATIONS.

Circumferences and areas may be calculated readily by several means. Set the "1" or "10" index of scale "C" to the symbol π on scale "D," and under the significant figure for the diameter on Scale "C" read the significant figures for the circumference on Scale "D." The inverse calculation gives diameters from known circumferences.

Areas may be calculated from the formula:—

Area = $0.7854 \times D^2$ or use may be made of the special marks C or C 1 on Scale "C."

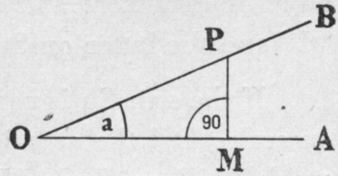
By setting the sign C in alignment with the first graduation mark on "A" there is obtained a complete table of diameters and areas with the former on Scale "C" and the latter on Scale "A."

If the sign C 1 is used and placed above the diameter on scale "D," the area is found on Scale "A" above the mark "10" on Scale "B." From this the volume of a cylinder may be determined. Set C 1 on Scale "C" over the diameter of the cylinder on Scale "D," and proceeding from "10" on Scale "B," read the volume on Scale "A" above the figure on Scale "B" corresponding to the length of the cylinder. Ascertaining the weight per unit volume of the material comprising the cylinder from appropriate tables or that on the rear of the Body of the slide rule, the weight of the cylinder is determined by placing "10" on scale "B" under the volume on Scale "A," and reading off the significant figures of the weight on Scale "A," above the figure corresponding to the unit weight of the material employed.

The Standard Model of the "Electronic Engineer's" Slide Rule is fitted with a single line Cursor. The Special

Cursor with three lines (obtainable to order) permits rapid calculation of circle quantities in the following manner: Set the Cursor line on the right to the diameter value on Scale "D," and read directly the area of the circle on Scale "A" under the Cursor line on the left. By multiplying the area so obtained by the length, the volume of a bar or cylinder is obtained by one setting of the Slide.

TRIGONOMETRICAL RATIOS.



$$\frac{MP}{OP} = \text{Sine of AOB} = \text{Sine a.}$$

$$\frac{OM}{OP} = \text{Cosine of AOB} = \text{Cos a.}$$

$$\frac{MP}{OM} = \text{Tangent of AOB} = \text{Tan a.}$$

$$\frac{OP}{MP} = \text{Cosecant of AOB} = \text{Cosec a.}$$

$$\frac{OP}{OM}\ \frac{\cancel{OM}}{\cancel{OP}} = \text{Secant of AOB} = \text{Sec a.}$$

$$\frac{OM}{MP} = \text{Cotangent of AOB} = \text{Cot a.}$$

RESONANT FREQUENCY AND WAVELENGTH CALCULATIONS.

A factor frequently required in calculations associated with Communication Engineering problems is the resonant frequency in Kilocycles per second and wavelength of circuits possessing inductance and capacitance, also the resonant frequency in cycles per second of audio frequency circuits.

Scale "B" of the Slide is provided with special markings $\sim$, λ, and Kc/s which permit the rapid solution of such problems. For radio-frequency circuits the inductance and capacitance factors are measured in microhenries and milli-microfarads to give convenient valued products on Scale "A." The Wavelength of a resonant circuit is determined as follows:—Locate on Scale "A" the figure corresponding to the product of the Inductance in microhenries, and the capacitance in milli-microfarads, then bring beneath this figure the symbol λ on Scale "B." The significant figures in the wavelength will now be found on Scale "D" under the left hand index "1" or right hand index "10" of Scale "C."

The "LC" product on Scale "A" corresponds to the actual markings for products between 1 and 100. Figures below and above this range are located by placing all odd products between 1 and 10 and even products between 10 and 100. For the "LC" product range between 1 and 100, the wavelength significant figures on Scale "D" should be multiplied by 100 when the Slide projects to the right, and by 10 when it projects to the left, while for "LC" products between 0.01 and 1 the "D" scale figures should be multiplied by 10 with the Slide to the right and read direct with the scale to the left.

EXAMPLES. (a) Find wavelength for resonant circuit of 60 microhenries and 0.35 milli-microfarads (350uuF). "LC" = 21. Wavelength = 2.73 × 100 = 273 metres.

The resonant frequency in kilocycles per second for this ciircuit is found by placing the symbol "Kc/s" on Scale "B" under the "LC" product—in this case 21—, and reading the significant figures of the frequency in kilocycles per second on the "C" scale, either above the left or right hand index markings "1" or "10" of Scale 'D." For "LC" products between 1 and 100, the significant figures on Scale "C" are multiplied by 1000 when the slide projects to the left, and by 100 when projecting to the right.

(b) Resonant frequency in Kc/s for "LC" = 21 = 1100 Kc/s.

"LC" products between 0.1 and 1 require the "C" scale figures to be multiplied by 1000 with the Slide to the right, and by 10,000 with the Slide to the left.

RESONANT FREQUENCY OF AUDIO FREQUENCY CIRCUITS.

Low frequency series and parallel resonance calculations enter into many problems associated with telephone, telegraph and power engineering. These frequencies have their "LC" product calculated in terms of Inductance in Henries, and capacitance in microfarads. The special marking $\sim$ on Scale "B" should be brought under the "LC" product on Scale "A" when the significant figures of the resonant frequency in Cycles per second will be found on Scale "C" above the index "1" or "10" of Scale "D." The "LC" product of Henries and Microfarads on Scale "A" corresponds to the actual markings for products between 1 and 100. Figures below and above this range are located by placing all odd products between 1 and 10 and even products between 10 and 100. For the "LC" product range between 1 and 100 the significant figures on Scale "C" should be multiplied by 10 with the Slide to the *right* and by 100 with the slide to the *left*. Estimation of the magnitude of "LC" and $\sim$ also the position of the decimal point will be made easy by reference to the following table:—

		Slide Position and Multiplication Factor	
"L.C." Range	Frequency Range C.P.S.	Right	Left
100 to 1	15.9 to 159	x10	x100
1 to 0.01	159 to 1590	x100	x1000
0.01 to 0.0001	1590 to 15900	x1000	x10000

The resonant frequency of a simple π section circuit of series Inductance and parallel capacitance—as

employed in a low pass rectifier filter circuit—should be determined from the "LC" value as calculated from the product of the inductance and the effective parallel, capacitance of the two condensers which operate as regards resonance as two *series* connected condensers paralleling the inductance. (NOTE. The effective capacitance of two series connected condensers may be calculated from the relationship: Effective capacitance equals the reciprocal of the sum of the reciprocals of the individual capacitances. The inverse scale on the centre of the Slide will prove valuable for this calculation.)

INDUCTANCE CALCULATIONS.

A calculation frequently required by Communication Engineers is that of the Inductance of an electrical winding. The type most frequently encountered in high frequency work is the single layer solenoid. Special markings on the inner Body of the Slide Rule permit the direct reading of Nagaoka's factor "K" in the inductance formula:—

$$\frac{(\pi \times D \times N)^2}{1000 \times B} \times K = \text{Inductance in microhenries.}$$

where D = diameter in centimetres; B = length in centimetres; N = total number of turns; K = Nagaoka factor.

The scale referred to permits the reading of factor "K" for all ratios of Diameter to Length between "O" (infinite length) and 25. To read this factor from the Slide Rule, set the left edge of the Slide to the D/B ratio on the inner Body, and read the significant figures of the "K" factor on Scale "D" under the left hand index "1" of Scale "C." Depending on the D/B ratio, this factor will be between 1.0 and 0.1; the significant figures on the scale being divided by 10.

EXAMPLES. (a) Resonant audio frequency of circuit consisting of inductance of 25 henries shunted by two series connected condensers of 2 microfarads each. "LC" = 25 x 1 = 25. Set $\sim$ mark on "B" scale under 25 on Scale "A," and read significant figures of 3.18 on scale "C," above right hand index of Scale "D." As "LC" figure is between 1 and 100, the frequency will be 31.8 cycles per second. Similarly "LC" of 0.0005 gives a resonant frequency of 2250 cps.

(b) Calculate inductance of solenoid winding of 100 turns on a former 10 centimetres diameter and 10

centimetres long. Set right end of Slide to D/B ratio of 1.0, and read off "K" factor on Scale "D" of 0.688. Formula now becomes:—

$$\text{Inductance in microhenries} = \frac{(\pi \times 10 \times 100)^2}{1000 \times 10}$$

$\times\ 0.688 = \dfrac{3140^2}{10{,}000} \times 0.688.$ Place Cursor at 3.14 on "D" scale and read the square on Scale "A" of 9.86 (equivalent to 9,860,000). Now divide by 10,000—placing 10 or 1 or scale "B" under 9.86—and then slide the Cursor to the position where 6.88 (corresponding to the 0.688 of the factor "K") on scale "B" comes on scale "A." A quick estimation of the decimal point position gives the inductance as 690 microhenries.

For layer wound windings a close approximation may be made by taking the mean diameter, and calculating for an equivalent solenoid of that diameter, length and total turns. Spiral inductances may similarly be approximated by taking the mean diameter of the winding, and depth of spiral as dimensions D and B in the abovementioned formula.

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